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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
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| 10/526,059 | 10/13/2005 | Alexandre Ellison | 35947-213490 | 2769 |

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| EXAMINER | |
|---|---|
| GUGLIOTTA, NICOLE T | |
| ART UNIT | PAPER NUMBER |
| 4174 | |
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**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 10/526,059 | ELLISON ET AL. | |
| | Examiner | Art Unit | |
| | Nicole T. Gugliotta | 4174 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☐ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1 - 6* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1 - 6* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *13 October 2005* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *10/13/2005*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

## DETAILED ACTION

### *Election/Restrictions*

1. Applicant's election of claims 1 - 6 in the reply filed on October 13, 2005 is acknowledged. Because applicant did not distinctly and specifically point out the supposed errors in the restriction requirement, the election has been treated as an election without traverse (MPEP § 818.03(a)).

### *Claim Rejections - 35 USC § 112*

2. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

3. A broad range or limitation together with a narrow range or limitation that falls within the broad range or limitation (in the same claim) is considered indefinite, since the resulting claim does not clearly set forth the metes and bounds of the patent protection desired. See MPEP § 2173.05(c). Note the explanation given by the Board of Patent Appeals and Interferences in *Ex parte Wu*, 10 USPQ2d 2031, 2033 (Bd. Pat. App. & Inter. 1989), as to where broad language is followed by "such as" and then narrow language. The Board stated that this can render a claim indefinite by raising a question or doubt as to whether the feature introduced by such language is (a) merely exemplary of the remainder of the claim, and therefore not required, or (b) a required

feature of the claims. Note also, for example, the decisions of *Ex parte Steigewald*, 131 USPQ 74 (Bd. App. 1961); *Ex parte Hall*, 83 USPQ 38 (Bd. App. 1948); and *Ex parte Hasche*, 86 USPQ 481 (Bd. App. 1949). In the present instance, claim 6 recites the broad recitation the wafer thickness preferably exceeds 150 mm, and the claim also recites thickness the wafer thickness exceeds 100 mm which is the narrower statement of the range/limitation.

### *Claim Rejections - 35 USC § 102*

4. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

5. Claims 1 – 2 are rejected under 35 U.S.C. 102(b) as being anticipated by Kordina et al. (Appl. Phys. Lett. **66** (2), January 1995).

6. In regard to claim 1, applicant claims a uniform silicon carbide single crystal with either an n-type or a p-type conductivity, characterized by that the crystal has a net carrier concentration less than $10^{15}$ $cm^{-3}$ and a carrier lifetime of at least 50 ns at room temperature.

7. Kordina et al. disclose the room temperature minority carrier lifetimes have been measured on 6H SiC epitaxial layers with residual *n*-type doping range from below $10^{14}$ $cm^{-3}$. Lifetimes as high as 0.45 us have been achieved for thick low-doped material (Abstract, page 1, columns 1 & 2). Kordina et al. does not disclose the SiC substrate to be a uniform single crystal, but a 6H SiC epitaxial layers substrate (Abstract, page 1, column 1).

8. It is inherently known that application of a low net carrier concentration could just as easily be applied to a single crystal SiC as to a SiC epitaxial layer. It is well known in the art that one would want to use a single crystal substrate, as opposed to a polycrystalline substrate.

9. In regard to claim 2, applicant claims the silicon carbide crystal wherein dopants conferring said *n*-type or *p*-type conductivity to the crystal are either shallow donors, comprising nitrogen, or shallow acceptors, comprising aluminum.

10. Kordina et al. disclose an aluminum acceptor and a nitrogen donor dopants for n-type epitaxial 6H SiC layers (Page 1, Column 2).

## ***Claim Rejections - 35 USC § 103***

11. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the

invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

12. Claims 1 - 6 rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious over Larkin et al. (U.S. Patent No. 5,709,745), in view of Precht (U.S. Patent No. 5,043,773).

13. In regard to claim 1, applicant claims a uniform silicon carbide single crystal with either an n-type or a p-type conductivity, characterized by that the crystal has a net carrier concentration less than $10^{15}cm^{-3}$ and a carrier lifetime of at least 50 ns at room temperature.

14. Larkin et al. disclose nucleation sites and/or the polytype of the substrate can control the type of SiC epilayer grown on the substrate. As illustrated in Fig. 4, 6H-SiC epilayers are grown on a 6H-SiC polytype substrate, which is referred to as homoepitaxial growth (Column 14, Lines 44 – 48). Larkin et al. obtained both p-type and n-type epilayers with room temperature carrier concentrations of $1 \times 10^{14}$ $cm^{-3}$ (Column 29, Lines 18 – 20). The Si/C ratio can be changed and/or selected at a single ratio to form low dopant concentrations for both *p*-type and *n*-type dopants in single crystal films which are less than $1x10^{16}$ $cm^{-3}$ and have been reproducibly obtained at dopant levels as low as less than about $8x10^{13}$ $cm^{-3}$ (Column 16, Lines 26 – 31). Larkin et al. discloses the improved CVD method can be used to grow crystals having increased carrier lifetimes. Carrier lifetime is another physical property of compound semiconductors that can be enhanced by growing purer crystals with lighter background defect concentrations. It is well known in the art that the bulk carrier lifetime increases

as the crystal defect concentration decreases. An improvement in this property could lead to smaller recombination/generation rates within a device resulting in improved performance for certain types of devices (Column 33, Lines 31 – 40).

15. Larkin et al. disclose single crystal SiC layers can be deposited homoepitaxial grown on a substrate. The substrate would be single crystal. Homoepitaxial layers would have the same crystal structure and elements as the substrate. The layered structured disclosed by Larkin et al. meets that of applicant. Therefore the expected carrier lifetime of the single crystal would be expected to be the same which applicant claims, absent in objective showing to the contrary. In the alternative, it would have been obvious to one skilled in the art at the time the invention was made to decrease the net carrier concentration in order to grow a purer crystal to increase the carrier lifetime.

16. In regard to claim 2, applicant claims the silicon carbide crystal wherein dopants conferring said n-type or p-type conductivity to the crystal are either shallow donors, comprising nitrogen, or shallow acceptors, comprising aluminum.

17. Larkin et al show further evidence of aluminum and nitrogen as dopants for SiC substrates. Larkin et al. disclose a SiC single crystal doped with p-type dopant such as aluminum (Column 16, Lines 4 – 6), and an n-type dopant such as nitrogen (Column 8, Line 44, Column 11, Lines 40 -41). Site-competition epitaxy has been successfully used for control of both Al and N doping, partly because Al substitutes for Si in the Si-

sites whereas N mainly substitutes for C in the C-sites of the SiC lattice when grown of the Si-face (Column 15, Lines 50 – 54).

18. In regard to claim 3, applicant claims wherein the crystal is provided in the form of a wafer being sliced from an originally produced crystal.

19. In regard to claim 4, applicant claims the crystal is provided as a polished wafer.

20. Larkin et al. disclose the SiC substrate is prepared by slicing a section from a SiC boule. Substrate may be cut such that the surface is slightly misoriented relative to the basal plane (Column 12, Lines 22 – 25). Larkin et al. disclose the substrate surface to be polished after cutting (Column 12, Lines 54 – 56). Contaminants and surface defects are removed from the substrate by proper cutting and polishing of the substrate surface and subsequent etching of the substrate surface. (Column 9, Lines 18 – 21).

21. In regard to claim 5, applicant claims the silicon carbide crystal wherein the surface of the crystal is either off-oriented towards a Miller index direction with an off-axis angle less than 1 degree or on-axis, that is parallel to a Miller index plane.

22. Larkin et al. disclose the SiC substrate may be cut such that the surface is slightly misoriented relative to the basal plane by some tilt angle. If SiC film layers are to be grown homoepitaxially on SiC substrate, the tilt angle is preferably greater than 0.1° (Column 12, Lines 28 – 29).

23. Basal planes are the horizontal planes of the structure in a hexagonal close packed (hcp) crystal in x-ray crystallography. The Miller Index of the basal plane is

(0001), which is one of the principle planes of a hexagonal close packed crystal. Larkin et al. disclose the SiC substrate may be cut such that the surface is slightly misoriented relative to the commonly known basal plane. It is possible to be off axis from the basal plane by greater than 0.1° and still be less than 1° off-axis relative to a Miller index plane (the basal plane).

24. In regard to claim 6, applicant claims wafers have a thickness that exceeds 100 um and preferably exceeds 150 μm.

25. Larkin et al. disclose the Si/C ratio can be changed and/or selected at a single ratio to form low dopant concentrations for both p-type and n-type dopants in single crystal films which are less than $1x10^{16}cm^{-3}$ and have been reproducibly obtained at dopant levels as low as less than about $8x10^{13}cm^{-3}$ (Column 16, Lines 26 – 31). Larkin et al. does not disclose the thickness of the SiC wafer. However, wafers must have result effective variable through routine experimentation. Therefore it would be possible to have a wafer thickness of greater than 100 or 150 microns, as further evidence by Precht et al (U.S. Patent No. 5,043,773). Precht et al. disclose metal carbide wafers with semiconductor devices having a thickness of 0.5 – 100 mm are preferred. These values correspond to a thickness of 500 μm to 1000 μm. (Column 14, Lines 6 – 7).

26. It would have been obvious to one skilled in the art at the time the invention was made for a SiC single crystal wafer to have a thickness of greater than 150 microns, as it is a result effective variable. In addition, it would be obvious to modify the disclosure of Precht et al. with a SiC wafer, as other metal carbide wafer substrates have been

shown to have a thickness greater than 150 microns. Absent a showing of criticality with respect to thickness (a result effective variable), it would have been obvious to a person of ordinary skill in the art at the time of the invention to adjust the thickness through routine experimentation in order to achieve the desired semiconductor thickness. It has been held that discovering an optimum value of a result effective variable involves only routine skill in the art. In re Boesch, 617 F.2d 272, 205 USPQ 215 (CCPA 1980).

## *Conclusion*

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Nicole T. Gugliotta whose telephone number is 571-270-1552. The examiner can normally be reached on M - F (first Friday off) 7:30 a.m. - 5 p.m. EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, D. Lawrence Tarazano can be reached on 571-272-1515. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/D. Lawrence Tarazano/
Supervisory Patent Examiner, Art Unit 4174

Nicole T. Gugliotta
Examiner
Art Unit 4174